DOCUMENT RESUME

ED 357 082 TM 019 861

AUTHOR Shotsberger, Paul G.
TITLE An Approach to Analyzing the Videotaped Problem Solving Behaviors of Individual Students.
PUB DATE Apr 93
NOTE 17p.; Paper presented at the Annual Meeting of the American Educational Research Association (Atlanta, GA, April 12-16, 1993).
PUB TYPE Reports - Evaluative/Feasibility (142) -- Speeches/Conference Papers (150) -- Tests/Evaluation Instruments (160)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Analysis of Variance; *Behavior Patterns; Check Lists; Classification; *Elementary School Students; Grade 6; *Individual Differences; Intermediate Grades; Organization; Personality Measures; *Problem Solving; *Protocol Analysis; Research Methodology; Student Behavior; *Videotape Recordings; Word Problems (Mathematics)
IDENTIFIERS *Strategy Choice; Vocalization

ABSTRACT

To generate a useful means of analyzing think-aloud protocols of individual students, and to determine the extent to which practical information might be derived from transcripts and videotapes, this project focused on the problem-solving behaviors of 17 sixth-grade students videotaped while solving routine textbook word problems. Using a checklist derived from prior research, problem-solving strategies were grouped in the following categories: orientation; organization; execution; and verification. Incidents of strategy use were calculated as percentages across individuals in the sample, and each category was submitted to a separate analysis of variance. Analysis allows determination of the effect that strategy use within a category had on strategy use across individuals. Within a category, particular strategies proved more natural or accessible for all students. For example, use of vocalizing calculations was the most common of the execution strategies. An opportunity for self-correction seemed to play a significant role in determining problem-solving behaviors. Overall, application of the strategies checklist proved effective for analyzing the protocols, and actions were effective for classifying behaviors. Checklist data were suitable for analysis, and the analysis provided useful information. Two figures and three tables provide study data. (Author/SLD)

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AN APPROACH TO ANALYZING THE VIDEOTAPED PROBLEM SOLVING BEHAVIORS OF INDIVIDUAL STUDENTS

Paul G. Shotsberger

School of Education

University of North Carolina - Chapel Hill

Paper presented at the 1993 annual meeting of the

American Educational Researchers Association, Atlanta, GA

TM019861

ABSTRACT

This project focused on the problem-solving behaviors of sixth grade students who were videotaped while solving routine, textbook word problems. The goals of the study were to generate a useful means of analyzing the think-aloud protocols of individual students and to determine the extent to which practical information might be gleaned from transcripts and videotapes concerning problem solving behaviors exhibited across individuals. Using a checklist of behaviors adapted from the work of Garofalo, Lester and their colleagues, problem-solving strategies were grouped under the categories of Orientation, Organization, Execution and Verification. Incidents of strategy-use were calculated as percentages across individuals in the sample, and each category of strategies was submitted to a separate analysis of covariance. Results of the analyses allowed a determination of strategy-use across individuals. Overall, application of the strategies checklist to the problem of analyzing protocols and actions proved to be sufficient for classifying the problem solving behaviors of individual students. Data from the checklists were suitable for statistical analysis, and results of the analysis provided useful information concerning strategy-use across individuals.

AN APPROACH TO ANALYZING THE VIDEOTAPED PROBLEM SOLVING BEHAVIORS OF INDIVIDUAL STUDENTS

OBJECTIVE

The National Council of Teachers of Mathematics (1991) has emphasized the need for methods of assessment which accurately reflect student problem-solving processes. Such assessments should allow teachers to determine the presence or absence of student behaviors such as the ability to formulate problems, to solve problems using different strategies, and to verify and interpret results. Additionally, teachers are to use these assessments as a basis for their instruction.

This project focused on the problem-solving behaviors of sixth grade students who were videotaped while solving routine, textbook word problems. The goals of the study were to generate a useful means of analyzing the think-aloud protocols of individual students, and to determine the extent to which practical information might be gleaned from transcripts and videotapes concerning problem solving behaviors exhibited across individuals.

THEORETICAL FRAMEWORK

Various researchers have posited methods of categorizing mathematical problem solving behaviors, concentrating primarily on cognitive and metacognitive factors (Schoenfeld, 1985; Lawson & Rice, 1987; Artzt, 1990). Perhaps the most extensive work done in this area has been carried out by Garofalo, Lester and their colleagues (Lester & Garofalo, 1982; Garofalo & Lester, 1985; Lester, Garofalo & Kroll, 1989). Garofalo and Lester (1985) identified and defined behaviors for four categories of strategies in mathematical problem solving: Orientation, Organization, Execution and Verification. Orientation strategies were those that promoted assessment and understanding of the problem situation; Organization strategies reflected the planning behaviors of the problem solver; Execution strategies were control or regulatory processes used during problem solving computations; finally, Verification strategies provided the problem solver with a

means of evaluating decisions and outcomes. A later report (Lester, Garofalo & Kroll, 1989) amplified and further defined these categories by studying the activities of seventh grade students solving non-routine word problems.

Insert Figure 1 About Here

The present study employed a checklist of problem-solving strategies (Figure 1), which represents a compilation of the latter two sources. The behaviors identified in these sources were considered appropriate for this study since the authors had focused their analyses on similar-age students and like mathematical tasks. Only the strategy of making trade-off decisions (e.g., accuracy vs. time) was left off of the list, since students in the present study had no time restrictions placed on their problem solving.

DATA SOURCE

Sexton (1987) videotaped 20 sixth grade students independently solving seven routine textbook word problems. Students were chosen from a stratified sample within one North Carolina school system. All students were above-average, as indicated by their most recent California Achievement Test scores and their previous year's mathematics grade; all subjects were volunteers; and all were paid a small stipend for their participation. Sexton employed the method of think-aloud protocols in recording the problem solving activities of the students. Data were collected for each subject on audio- and videotape during 45 minute problem-solving sessions.

Students were instructed to verbalize every thought they had while solving the problems. They were also told that the researcher would not be able to answer any questions, and that the only comments that would be made to students would be "Tell me what you're thinking" if they had been silent for more than five seconds, and "That's correct" or "That's incorrect" when the students said they were done working a problem. This last point is important for the present study because the presence of performance

feedback provided an opportunity to determine which students had solved a problem correctly on the first try, and which students had required more than one try to solve a problem. Students were allowed to solve two practice problems before solving the problems analyzed in the study. No post-session interviews were conducted with the students other than having students order the seven problems according to perceived difficulty level.

METHOD

The present study re-analyzed the videotapes and transcripts of 17 successful problem-solvers working on three moderately difficult problems (difficulty level was determined by the average time required to solve a problem and the percentage of students able to solve it). Each problem included some unique aspect of routine mathematical word problems: the presence of extraneous information (Problem 1), the need for quantity conversion (Problem 2), or the utility of using a diagram (Problem 3). The following problems were solved:

Problem 1 — Ears of corn sell for 5 for $0.95 at the vegetable stand. Mrs. Jones bought 10 ears of corn. How much does each ear of corn cost?

Problem 2 — What do 30 oranges cost at 60 cents per dozen?

Problem 3 — In Fred's room, there are 2 shelves on one wall. The first is 3 ft. off the floor, the second is 3 ft. above that. This last shelf is 2 ft. from the ceiling. How high is the room?

For each problem, strategy-use for each student was classified as either present or absent on the Figure 1 checklist. A limitation of this study is that problem-solving behaviors for the sample were only classified by one rater, and therefore no estimate of the reliability of this classification is possible.

The sample was divided into two groups for each problem: those students who solved a particular problem on the first try, and those students who required more than one try to solve a problem. An analysis of covariance (ANCOVA) was conducted for

each category of strategies (Orientation, Organization, Execution, Verification) across all 17 students. The independent variables were the number of tries needed to solve a problem (one or more than one) and the strategies for the different categories (which varied for each category). The covariate was the problem that was solved, entered as a set of dummy variables due to the categorical nature of the variable. The dependent variable was the percentage of students in a certain group using a strategy for a particular problem (e.g., 39% of students in the first try group used the strategy of Rereading for Problem 3). Therefore, for each analysis, there were six observations (two groups, three problems) for every strategy.

HYPOTHESES

There were two hypotheses that were tested using the above methodology. First, it was hypothesized that a significant effect would be found for the independent variable of number of tries needed to solve a problem; specifically, strategy use for each category of strategies was hypothesized to increase with the number of tries for a problem. Second, it was conjectured that there would be a significant effect resulting from the strategies used within each category of strategies; that is, that some strategies for each category would prove to be either significantly more or less accessible for the students of the sample. Specifically, based on the research of Lester and Garofalo (1982), elementary-age students would not be expected to routinely employ the strategies of Analysis of information and conditions, Monitoring progress of local/global plans, and Checking for reasonableness.

RESULTS

Think-aloud protocols and videotaped actions varied widely across individual students in the sample. Examples of protocols or actions encountered during the study, which serve to illustrate the use of each strategy, are presented in Table 1.

Insert Table 1 About Here

Figure 2 breaks down, by category, student strategy-use for the word problems of the study. These bar graphs are intended as a helpful reference for the discussion that follows on the ANCOVA results.

Insert Figure 2 About Here

Table 2 shows each strategy category's adjusted mean percentages for the independent variables. For each category, there were no significant interactions between

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Insert Table 2 About Here

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the covariate and the independent variables, indicating that the use of a particular strategy and the number of tries required to solve the problem were not significantly influenced by the type of problem being solved. Additionally, none of the analyses produced a significant interaction between the independent variables, encouraging investigation of the main effects for each category.

For all categories of strategies, use of a particular strategy was the only significant main effect ($p<.01$ in each case). Thus, the first hypothesis concerning a significant main effect for number of tries needed to solve a problem was not supported by the data. The main effect of strategies for the different categories resulted in multiple-R^2 values of .72 for Orientation, .67 for Organization, .77 for Execution and .59 for Verification. Based on the grand means of Table 2, the Organization strategies were used by the largest percentage of students (56.67%), while the Verification strategies were used by the smallest percentage (18.17%).

Tukey's HSD was calculated for each category of strategies in Table 2 in order to determine which strategies differed significantly from each other ($p<.05$). The strategies that resulted from some type of task prompt (Comprehension and Performance of local actions) have not been included in the following list. For the category of Organization, Drawing a diagram was found to be significantly different from both Global planning and Local planning; however, Drawing a diagram was utilized less often than the other Organization strategies, primarily because it was only applicable for one problem. Under the category of Execution, Vocalizing calculations differed significantly from Crossing-out discarded calculations. Vocalizing calculations may at first seem to be a natural outcome of the think-aloud protocols, but recall that students were only instructed to verbalize their thoughts during problem solving, not their visible processes. Finally, for the category of Verification, Evaluation of orientation and organization differed significantly from both Checking for reasonableness and from Estimation before solution, which were both under-utilized by the students of the sample. Thus, in terms of the second hypothesis, certain of the strategies did emerge as being significantly more or less accessible for students; however, whereas the strategies of Analysis of information and conditions, Monitoring progress of local/global plans, and Checking for reasonableness were all hypothesized to be strategies that would be used infrequently, only Checking for reasonableness was used significantly less often.

Data relating to group membership (first try/more than one try) were also analyzed to further clarify the determining factors of strategy-use. Overall, first-try success rates for each problem were 82% for Problem 1, 65% for Problem 2, and 77% for Problem 3. Table 3 presents adjusted mean percentages for strategy by number of tries within each category of strategies. Though there was a general trend across all categories

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Insert Table 3 About Here

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toward the percentage of students using strategies to increase with the number of solution attempts, only the Organization strategies did so exclusively. Differences between groups were most pronounced for the categories of Orientation and Verification. Interestingly, Assessment of familiarity with task and Pen movements were only employed by those students correctly solving problems using more than one try, though Pen movements occurred only once.

In general, strategy-use for the more-than-one-try group resulted from student solutions becoming more thoughtful and careful after the first try. Strategy-use certainly was prompted by problem context; however, the use of particular problem-solving strategies appeared at times to be more directly affected by students' knowledge of an incorrect answer (resulting in a second or third try).

DISCUSSION

It should not be assumed that the Figure 1 checklist represents some definitive taxonomy of problem-solving behaviors, or that this same checklist can or should be used without modification for students of differing age groups. This checklist resulted from a synthesis of sources (Garofalo & Lester, 1985; Lester, Garofalo & Kroll, 1989) which focused on students and mathematical tasks similar to those in the present study . Two general observations can be made concerning the study's sample.

First, within a category of strategies, particular strategies proved to be more natural or accessible for students. For this study, use of Vocalizing calculations was the most common of all of the unprompted Execution strategies; while Evaluation of orientation and organization distinguished itself as the most prevalent of the Verification strategies. Note that this result suggests neither the most effective nor the most efficient problem-solving strategies, since for many students the problems were not solved until the second or third try. Additionally, no instruction in problem-solving strategies preceded the videotaping. The method of analysis presented in this paper should prove beneficial in an experimental setting where an instructional treatment takes place before

the problem solving (e.g., Lester, Garofalo & Kroll, 1989), such that it is possible to compare the strategy-use of those students receiving the treatment with those in a control condition.

Second, an opportunity for self-correction seemed to play a role in determining student problem-solving behaviors. Students in this study enhanced their own strategy-use merely as a result of being told that their solutions were incorrect and being afforded additional opportunities to solve the problems. This was especially true of Assessment of familiarity with task within the Orientation category. This result supports the constructivist notion that students should be given time to examine their own work critically, engaging in what Confrey (1990) calls the "reflective process;" and that when these reflections are captured on videotape they represent a rich source of information about student problem-solving behaviors.

Overall, application of the strategies checklist to the problem of analyzing protocols and actions proved to be sufficient for classifying the problem solving behaviors of this sample of sixth grade students. Data from the checklists were suitable for statistical analysis, and results of the analysis provided useful information concerning strategy-use across individuals.

REFERENCES

Artzt, A. F. (1990). *Protocol analysis of group problem solving in mathematics: A cognitive-metacognitive framework for assessment.* Paper presented at the annual meeting of the American Educational Research Association, Boston, MA.

Confrey, J. (1990). What constructivism implies for teaching. *Journal for Research in Mathematics Education*, Monograph Number 4, 107-122.

Garofalo, J., & Lester, F. (1985). Metacognition, cognitive monitoring, and mathematical performance. *Journal for Research in Mathematics Education,* 16(3), 163-176.

Lawson, M.J., & Rice, D.N. (1987). Thinking aloud: Analyzing students' mathematics performance. *School Psychology International,* 8, 233-243.

Lester, F., & Garofalo, J. (1982). *Metacognitive aspects of school students' performance on arithmetic tasks*. Paper presented at the meeting of the American Educational Research Association, New York.

Lester, F., Garofalo, J., & Kroll, D. (1989). *The role of metacognition in mathematical problem solving: A study of two grade seven classes.* (Final report, Mathematics Education Development Center, Indiana University, 1989).

National Council of Teachers of Mathematics (1991). *Professional standards for teaching mathematics.* Reston, VA: NCTM.

Schoenfeld, A.H. (1985). *Mathematical problem solving.* Orlando, FL: Academic Press.

Sexton, R. (1987). *Problem-solving processes used by sixth-grade students in solving routine mathematics word problems* (Doctoral dissertation, University of North Carolina, 1987).

Figure 1. Strategies Checklist.

Student #____ **Problem #____**

Orientation (assessment and understanding of the situation):

_____ Comprehension
_____ Analysis of information and conditions
_____ Assessment of familiarity with task
_____ Initial and subsequent representation
_____ Assessment of level of difficulty and chances of success
_____ Rereading
_____ Listing data
_____ Pen movements

Organization (planning behavior and choosing actions):

_____ Identification of goals and subgoals
_____ Global planning
_____ Local planning (implementing global plan)
_____ Drawing a diagram

Execution (regulation of behavior):

_____ Performance of local actions
_____ Monitoring progress of local/global plans
_____ Vocalizing calculations
_____ Crossing-out discarded calculations
_____ Subtotaling or tallying
_____ Shifting gears

Verification (evaluation of decisions and outcomes):

_____ Evaluation of orientation and organization
_____ Evaluation of execution
_____ Checking for reasonableness
_____ Estimation before solution

Adapted from Garofalo and Lester, 1985; Lester, et al., 1989

Table 1

Examples of Protocols or Actions for the Different Strategy Categories

Orientation

Comprehension - Reading the problem aloud for the first time.

Analysis of information and conditions - "Mrs. Jones bought 10 ears of corn doesn't have anything to do with it."

Assessment of familiarity with task - "Not sure I know how to solve this problem."

Initial and subsequent representation - "The second [shelf] is the same as the last one."

Assessment of level of difficulty and chances of success - "Pretty easy problem."

Rereading - Reading the problem aloud for a second, third or fourth time.

Listing data - Writing out information stated in the problem.

Pen movements - Using the pen/pencil to attend to words or calculations.

Organization

Identification of goals and subgoals - "You have to find out how many cents one orange is worth."

Global planning - "...how many times a dozen goes into 30."

Local planning - "First you divide 12 into 30."

Drawing a diagram - Attempting a pictorial representation of the problem.

Execution

Performance of local actions - Carrying out planned mathematical operations.

Monitoring progress of local/global plans - "Now I have 6 more oranges left."

Vocalizing calculations - "2 feet plus 3 feet plus 3 feet gives you a total of 6 plus 2 is 8 feet."

Crossing-out discarded calculations - Erasing or marking out previous work that is no longer relevant.

Subtotaling or tallying - Maintaining a running total on paper during calculations.

Shifting gears - "I'm gonna try and do this over."

Verification

Evaluation of orientation and organization - "I misunderstood the question."

Evaluation of execution - "Gonna see if I divided right."

Checking for reasonableness - "Can't be right. Can't have a remainder."

Estimation before solution - "If I'm correct it should be about 8 -- 19 or 20."

Figure 2. Incidents of Strategy Use by Category and Problem (n=17).

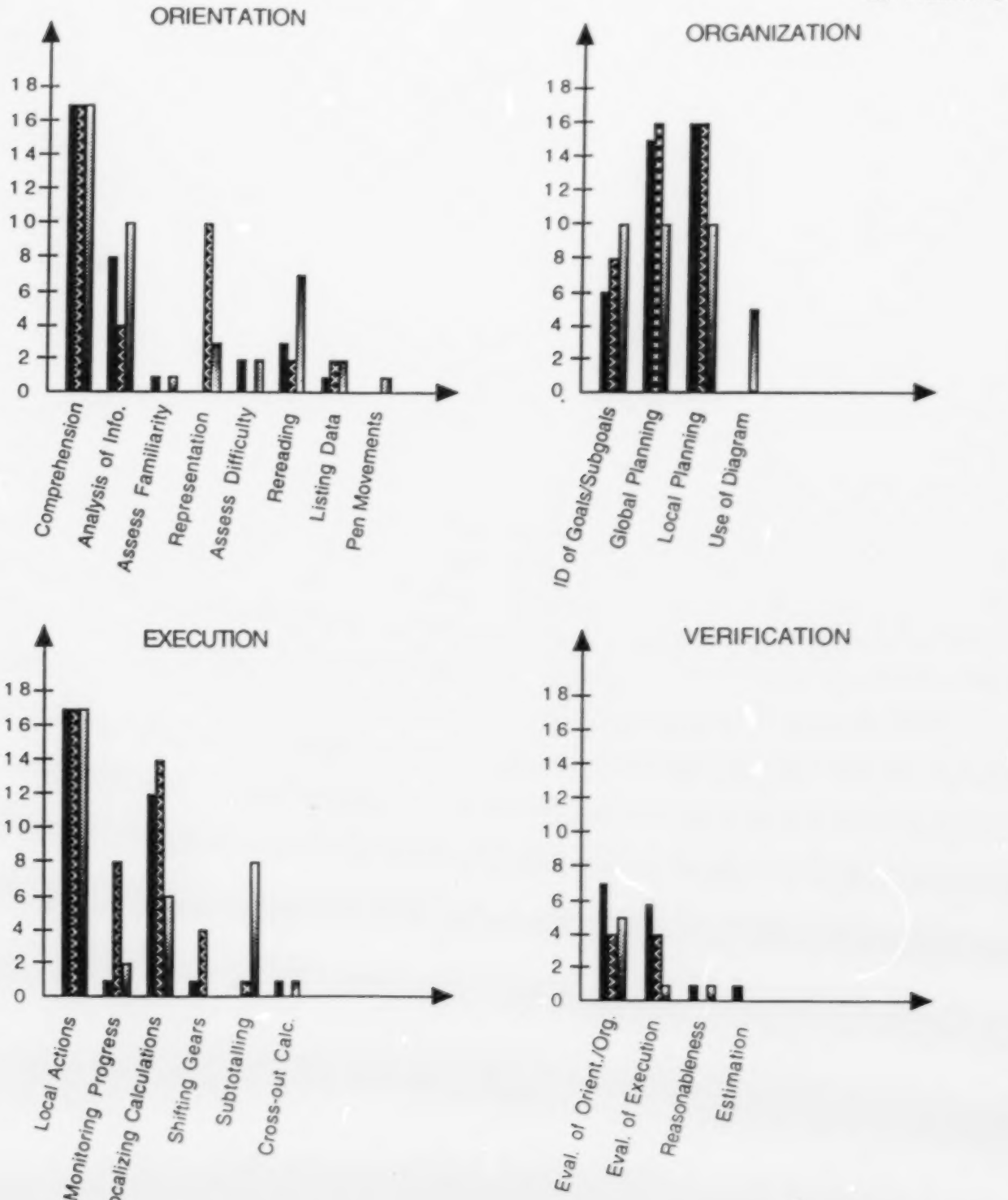

Table 2

Adjusted Mean Percentages for Strategy and Number of Tries

Orientation (Grand Mean = 30.08)

Number of Tries:	One	More Than One
	24.04	36.13

Strategy:	Comp.	Analysis of Info	Assess. of Fam.	Represent.	Assess. of Diff.	Rereading	Listing Data	Pen Move.
	100.00	38.00	9.67	30.00	9.17	35.83	13.83	4.17

Organization (Grand Mean = 56.67)

Number of Tries:	One	More Than One
	52.92	60.42

Strategy:	ID of Goals & Subgoals	Global Planning	Local Planning	Use of a Diagram
	47.50	81.50	82.67	15.00

Execution (Grand Mean = 32.29)

Number of Tries:	One	More Than One
	29.67	34.90

Strategy:	Local Actions	Monitor. of Prog.	Vocalize Calc.	Cross-out Calc.	Shifting Gears	Subtotal.
	100.00	19.67	59.67	9.67	18.17	18.83

Verification (Grand Mean = 18.17)

Number of Tries:	One	More Than One
	10.67	25.67

Strategy:	Eval. of Orient./Org.	Eval. of Execution	Check of Reasonable.	Estimation Before Solution
	40.67	24.00	2.50	5.50

Table 3

Adjusted Mean Percentages for Strategy by Number of Tries

Orientation

	Strategies							
	Comp.	Analysis of Info	Assess. of Fam.	Represent.	Assess. of Diff.	Rereading	Listing Data	Pen Move.
No. of Tries								
One	100.00	42.67	0.00	21.00	7.33	16.00	5.33	0.00
More Than One	100.00	33.33	19.33	39.00	11.00	55.67	22.33	8.33

Organization

	Strategies			
	ID of Goals & Subgoals	Global Planning	Local Planning	Use of a Diagram
No. of Tries				
One	45.00	79.67	82.00	5.00
More Than One	50.00	83.33	83.33	25.00

Execution

	Strategies					
	Local Actions	Monitor. of Prog.	Vocalize Calc.	Cross-out Calc.	Shifting Gears	Subtotal.
No. of Tries						
One	100.00	22.67	64.00	2.67	3.00	15.33
More Than One	100.00	16.67	55.33	16.67	33.33	22.33

Verification

	Strategies			
	Eval. of Orient./Org.	Eval. of Execution	Check of Reasonable.	Estimation Before Solution
No. of Tries				
One	23.00	14.67	5.00	0.00
More Than One	58.33	33.33	0.00	11.00